A REVIEW OF THE NATURE AND PROBLEM OF IMPULSE NOISE DAMAGE TO THE SOLDIERS HEARING AND ITS PREVENTION

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SUMMARY: This paper reviews the historical background to and nature of gunfire induced impulsive noise damage to the hearing. The implications for the soldier and his employment and for the Army Medical Services are discussed. It is concluded that, despite much progress in recent years to safeguard the soldier's hearing, a more intense effort based upon valid epidemiological evidence and within the limits of available resources is necessary.

Introduction

The production of noise is the biggest growth industry of our day: road traffic, aircraft industry and the ubiquitous hi-fi. These hazards are there for all; the soldier has had, since the introduction of gunpowder, the additional hazard of gunfire produced impulse noise. This paper reviews the nature and problem of this hazard to the soldiers hearing and examines the problems of prevention.

Historical background

With the widespread use of gunpowder from the 14th century onwards an increasing number of soldiers—men-at-arms, master gunners, landsknechts and the like, must have suffered some deterioration in their hearing due to their noisy work. Evidence that noise anything other than a nuisance however came slowly. In 1593 Fabricius Hildanus described the case of Johannes Textor, a soldier, who, being asleep, was woken by the discharge of a pistol close to his ear. He woke in considerable pain, vomited and was deaf in that ear for some time afterwards.

Later record of impulse noise induced deafness was chiefly concerned with percussive impulse noise. Ramazzini remarked upon the deafness of coppersmiths in his book "*De morbis artificum diatriba*" (1713), but the first carefully observed and accurately reported finding of such occupational deafness was made by Fosbroke in 1831. He had already noted Dr. Parry's report of the deafness of Admiral Lord Rodney following exposure to the noise of 80 broadsides in a naval engagement in 1782 when he described in a lucid account the occupational deafness of blacksmiths. He established that the deafness was indeed occupational, that it followed an insidious course marked by the presence of tinnitus associated with the steady decline of auditory acuity into middle age. He also voiced suspicion that the deafness was due to nerve damage.

Despite this authoritative account little note was made of the problem judging by the lack of reference to it in the medical literature of the time. Impulse noise did bother some people; witness the well known example of the request for advice made in a letter to the "*Lancet*" in the 1860's from a Volunteer who had been deafened by rifle fire.

The progression of events from the late 19th century to the years just prior to the Second World War has been reviewed by Bunch (1937). He relates that reports on

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gunfire induced deafness were made in 1874, 1880, 1888, 1889 and the Spanish- American War period alone resulted (among other things) in six independent reports describing deafness due to exposure to large calibre naval gunfire. During the First World War similar reports came in a flood and in the post war period more work was done that differentiated the condition from the deafness due to progressive middle-ear disease and that due to otosclerosis.

Thus, by the middle thirties, the damaging properties of very loud impulse noise on human hearing were well recognised. Generally it was known that explosive or percussive noise caused a high frequency nerve deafness usually of insidious onset and roughly proportional to the loudness of the noise and the duration of exposure to it.

With millions in uniform and exposed to the noise of warfare, the period 1939-1945 saw the publication of many papers describing hearing injury as a response to a large variety of impulse noise stimuli. Since the war both steady-state noise and impulse noise have been increasingly recognised as potent causes of occupational disease and the attention of investigators in the medical and engineering worlds, management and workers has been focussed upon the problem. However the plight of the occupationally deaf themselves has only recently begun to be accorded the attention it deserves.

The physical nature of impulse noise and its measurement

Physical nature

The term 'noise' is based upon subjective valuation of a particular sound or combination of sounds. Sound, both steady-state and impulsive is defined as "a mechanical disturbance, propagated in an elastic medium of such a character as to be capable of exciting the sensation of hearing". (British Standards Institute, 1969). The only elastic medium that concerns us is, of course, air. It will be recalled that steady-state sound is propagated as a wave motion, the waves being areas of alternate compression and rarefaction of air. If the pressure changes are plotted against time a sinusoidal curve is produced.

In contradistinction, with impulse noise (sound) there is no regular propagation of a wave motion but an irregular sequence of pressure changes is produced. In a simple non-reverberant pulse the pressure changes are characterised by a very rapid rise to a peak pressure followed by a slow decline to a longer-lived sub-ambient pressure phase. The duration of the whole varies according to source but is usually of the order of a few milliseconds (ms).

Reverberant impulse noise, for example the sort of noise produced by firing weapons in a relatively enclosed space with reflective surfaces, is rather different. There is a very rapid rise to peak pressure then an equally rapid decline to a similar but negative (relative to the ambient) value. This process is repeated producing a rapid violent oscillation between gradually declining peaks of positive and negative pressure and consequently reverberant impulses are usually of very long duration when compared to the simple pulse.

Measurement of impulse noise

The unit of measurement is the decibel (dB) which in terms of sound pressure is expressed as

$$\text{Sound pressure level in dB (SPL)} = 20 \log_{10} \frac{\text{Observed sound pressure}}{\text{Reference sound pressure}}$$

By convention the reference sound pressure is 2×10^{-5} Newtons per square metre (N/m²). Physical measurement of impulse noise is normally by a combination of microphone, oscilloscope and camera. The ordinary electronic sound level meter is of limited value.

Assessment of hearing

For many years hearing was tested by a combination of whispered voice techniques and the use of tuning forks tuned to various suitable frequencies. Some examiners used the ticking of a watch to test their patients; this method, like the whisper test, obviously suffered from a lack of standardisation.

Not surprisingly, although hearing loss due to impulse noise was identified early, its qualitative character was misunderstood. In the 1920's an instrument was developed that used standard pure tones at standard frequencies to test hearing. This was the now familiar audiometer.

In the Army today, despite the proven value of audiometry, consideration of the cost of equipment, sound proofed testing facilities and the provision and training of audiometrists have led to the retention in many situations of the crude whisper test. Cable and Morris (1971) found a moderate degree of correlation between results using the two techniques but for all intents and purposes audiometry is the only accurate method of assessing hearing.

Sources of risk to the soldiers hearing

There are two main groups of impulse noise sources that hazard the soldier's hearing. These are industrial tools and weapons.

Industrial tools

Nearly all impulse noise from industrial tools is contributed by the various pneumatic tools including pneumatic picks, chisels and hammers. Their use however is limited to a relatively few men in some trades in the Royal Engineers and Royal Electrical and Mechanical Engineers. Fairly effective measures for the control of noise hazard are in being under the provisions of various workshop regulations.

Weapons

Weapons constitute by far the greatest source of impulse noise hazard in the Service. They are of diverse size, type and employment ranging from 9 mm pistols to 120 mm anti-tank guns, machine guns, artillery pieces and mortars. Noise hazard from weapons is thus likely to be very variable depending upon the type of weapon, the circumstances of its use, the type of ammunition, the size of the charge and the position of the marksman or gun number relative to the weapon.

Investigation of noise sources

Scientific investigation of the noise hazard due to weapons has been far from uniform. Most work has in fact been with small-arms and, in particular, the rifle. While

this may seem an undue narrowing of the field of investigation, the rifle is not only the easiest and cheapest weapon to work with but represents by far the greatest single risk to the hearing of the soldier for the following main reasons:

(a) All soldiers, even clerks, storemen and nominal non-combatants, have to fire their personal weapons at least annually in range classification. Most soldiers are equipped with the SLR: a smaller proportion carry the SMG.

(b) A comparatively large number of rounds is fired by each individual throughout his service life. This may vary from a minimum of perhaps 50 to 60 rounds annually during classification for an orderly-room clerk to an exposure of many thousands of rounds annually incurred by such men as small-arms instructors.

Therefore it can be seen that the noise hazard due to small-arms is widespread with most soldiers exposed, some to an intense degree. Further, all that has been said above refers to peacetime conditions. On active service, exposure is frequently of a very much higher order even in "limited" war or internal security operations.

The effect of weapon firing upon the hearing

It has already been mentioned that by the outbreak of the Second World War the broad picture of impulse noise hearing damage was known in essential. A number of confirmatory reports appeared immediately post-war but in this country the work on the subject was given new impetus in the late 1950's by the introduction of the high-velocity SLR which replaced the No 4 Short Muzzled Lee-Enfield (SMLE). It was quickly realised that the SLR produces an average noise level about 7 dB higher than the SMLE; an increase in intensity of more than fourfold and a more than doubling of SPL (Coles 1962).

Since the recognition of this problem, research has centred largely on attempts to correlate the duration and intensity of exposure with variations in individual susceptibility to hearing damage with a view to formulating damage risk criteria and improving preventive measures.

The actual effects of noise on the hearing have been broadly categorised as: (a) Temporary threshold shift (TTS). (b) Permanent threshold shift (PTS). (c) Acoustic trauma. These effects will now be separately considered.

Temporary threshold shift

Burns (1973) described TTS as "This component of the total effect of noise on the ear is virtually always present to some extent during the following exposure to noise, irrespective of whether permanent threshold shifts ensue. Almost any sound stimulus applied to the ear will result in an alteration in the hearing level and this may last, depending upon the nature of the exposure in any given individual, for a period which may be measured in seconds, hours, days or apparently even months after the cessation of the sound".

Also, TTS is often accompanied by tinnitus and occasionally by vertigo. Wagemann (1965), reporting on subjective complaints of people after exposure to impulse noise, records that the sensation of deafness and tinnitus usually, but not always, occur together and that headache is a concomitant symptom as a sole entity or associated with deafness. This account tallies very closely with that of Fosbrooke in 1831.

More technically, discussion of TTS is incomplete without reference to the role of the acoustic reflex (AR). This is the reflex contraction of the tensor tympani and stapedius muscles which causes a damping of vibration transmission through the middle ear. The reflex is triggered by sound with an activation threshold of about 80 dB. An effective AR will thus reduce the amount of sound energy arriving at the cochlea and minimise TTS which must be assumed to be due to damage or overstimulation of the organ of Corti. As long ago as 1935 Hallpike estimated that the reduction could be as much as 6 dB; that is a reduction in intensity to a quarter the level arriving at the tympanum. However this reflex takes about 10 ms to begin and most impulse noises will reach peak intensity within this time. The value of AR in protecting the inner ear is therefore questionable and considerable research time and energy has been expended in attempting to relate it to variations in TTS.

In 1946, Murray and Reid as part of a comprehensive survey of weapon-caused hearing damage, remarked that the TTS following exposure to x rounds from the SMLE was greater than that due to exposure to x rounds fired from a Bren gun (light machine-gun). This difference was ascribed to the maintenance of reflex tone in the latter case whereas the discrete rifle shots resulted in pulses of too short duration to allow protection by AR.

It has since been asserted (Coles and Knight 1965) that some individuals, as a result of experience of exposure to impulse noise, may be able to induce AR voluntarily or at least maintain an increase in reflex tone when the pulse is repeated. Coles had previously (1961) concluded as a result of experiment that TTS diminishes with consecutive exposure to impulsive noise, explained as being partly due to an increase in recovery rate and partly due to a conditioning of the acoustic reflex. Some subjective support for this view was provided by reports from the experimental subjects that they found an unexpected pulse much more unpleasant than that when they had been given prior warning.

In 1969, Brasher, Coles, Elwood and Ferres examined middle-ear muscle activity in 16 normal hearing subjects. They found by exposing the subjects to pistol shots the AR could be measured with an electronic impedance meter. The results showed that an anticipatory effect is indeed present. Nevertheless the researchers failed to establish any correlation between TTS and AR or anticipatory contraction and concluded that middle-ear muscle activity had little importance in the reduction of auditory hazard. Clearly, the protective properties of AR in impulse noise induced TTS must still be regarded as unproven and unlikely to be significant.

Recovery from TTS seems to be very variable according to the nature of the original noise stimulus and individual idiosyncrasy. Coles in 1962 found that recovery varied between subjects exposed to the same noise stimulus from less than 20 minutes to longer than 4 days.

Experimental work on rhesus monkeys however, (Luz 1970, Luz and Hodge 1970) has shown that recovery from impulse noise induced TTS differs from that following steady-state noise induced TTS. In the former case recovery seems to be diphasic being initially a function of the logarithm of the recovery time up to about 10 minutes. This phase is followed by a secondary shift maximum at 30-100 minutes post-exposure.

Recovery from steady-state noise induced TTS proceeded linearly as a function of the logarithm of the recovery time.

Regarding the degree of individual idiosyncrasy, Elwood (1967), assuming that the occurrence and degree of TTS following exposure to noise is related to the possible hazard of permanent hearing damage for the individual, found that in 151 men tested by exposure to rifle fire, a TTS of 20 dB+ was found in 37 men (24.5 per cent) after 20 pulses, in 29 (19.2 per cent) after 60 pulses, in 13 (18.6 per cent) after 120 pulses and in 72 (47.7 per cent) no appreciable TTS was observed even after 120 pulses. This evidence suggests that some individuals are refractory to TTS and, possibly, permanent hearing damage at this level of stimulation. This of course has important implications for the prevention of hearing as will be seen below.

Permanent threshold shift and acoustic trauma

The terms permanent threshold shift and acoustic trauma both refer to a state of permanently impaired hearing. Permanent threshold shift is the condition likely to follow exposure to excess steady-state or impulse noise.

Following exposure to damaging noise it may be impossible to predict to what extent the subsequent threshold shift will be temporary or permanent but the term permanent threshold shift is reserved for conditions that may be assumed to have little chance of recovery with time. Luz (1970) has attempted to correlate PTS with the second phase of the diphasic TTS mentioned above but the results of such a limited animal study require confirmation. Generally, the degree and length of exposure required to produce TTS seems to be dependant upon several variables, probably the most important being individual variation in susceptibility (Stewart and Barrow, 1946).

The overall relationship between temporary and permanent threshold shifts, as indicated above, is even now not completely understood but for protective purposes it is assumed that susceptibility to TTS following a given exposure to noise is positively correlated with the liability of incurring permanent hearing loss.

Acoustic trauma describes a condition of sudden aural damage from short-term or, indeed, single exposure to impulse noise. If the blast pressures are considerable the cochlear damage resulting may be associated with rupture of the tympanum, haemorrhage and damage to the auditory ossicles. Murray and Reid (1946) put a value of about 8 lb f in² (1.16×10^{-3} N/m²) required in a blast pulse to produce such damage.

As far as the soldier is concerned such gross damage or lesser degrees of acoustic trauma are only likely to ensue from incautious exposure to explosions, artillery fire and, in particular, from the discharge of large calibre recoilless anti-tank guns.

Prevalence of impulse noise induced hearing damage in soldiers

It has been described above that nearly all soldiers in the British Army are exposed to a greater or lesser degree to impulse noise hazard. It is also true that there is much variation in susceptibility to hearing damage and some individuals appear to be almost completely refractory. For these reasons alone, discounting reasons with regard to practicability that will be discussed later, the true prevalence of hearing damage has not been assessed and, even now, no large scale epidemiological survey is being undertaken.

Past studies give some guide. In 1944, Collins, in a report on otological damage in battle casualties at the battle of Tobruk, found that of 885 casualties, 218 (24.6 per cent)

had traumatic perforations of the eardrums with an accompanying mixed middle and inner ear deafness. From what has already been said above the likelihood of acoustic trauma being present was probable in a high proportion of these men but unfortunately no long term follow-up was possible to confirm this. In the same year (1944) Marshall-Taylor estimated that there would be 250,000 cases of aural damage among United States servicemen at the end of the War.

Both these reports are describing "worst case" situations; that is, a total war with very large numbers of men exposed to severe noise hazard over long periods of time. It may be argued that comparable results would not be obtained among British soldiers in time of peace. However in 1962, Coles described a series of 202 Royal Marine recruits who had a total exposure to about 300 rounds of 7.62 mm rifle fire during training. Although these men were provided with ear defenders, one squad made little use of them and at the end of a three week period approximately one third of the men had a hearing loss of not less than 25 dB at 3, 4 and 6 KHz, or 30 dB at 8 KHz in one or both ears. Coles and Knight in 1965 also pointed out that some men presenting as recruits are already deaf from rifle firing done in Army Cadet Force units or from private shooting with shotguns. These men are very vulnerable to serious hearing loss if further exposed to rifle firing during training.

In 1965, Livesey surveyed a randomly selected group of 100 infantrymen from different regiments. Each was examined to exclude gross ear pathology and all had subjectively normal hearing. Audiograms were then recorded for each man. From the total of 100, 54 cases of hearing damage were found. Of the 200 ears examined, 93 showed evidence of hearing damage of which 32 had a *minimum* loss of 50 dB for frequencies of 3-6 KHz. He further showed that of 39 bilateral cases, the left ear tended to be more severely affected than the right (supporting to some extent the commonly held opinion among soldiers that a man firing on a range suffers most from the discharge of his left-hand neighbour's rifle), a point also made by Meyrick in 1946.

Of these 39 bilateral cases, 18 were non-commissioned officers (NCOs) compared with 6 of 46 men without hearing damage. This again tends to confirm (without statistical analysis) that length of exposure and possible employment as a small-arms instructor, which infantry NCOs usually are at some stage of their career, greatly increases the risk. If the result of this report may be reasonably projected, there must be several thousands of men in the Army with damaged hearing.

Prevention of hearing damage due to impulse noise

Damage risk criteria

The first essential in the prevention of noise hazard is the recognition of the existence and size of the problem. This should be closely followed by accurate assessment of its severity.

With regard to the hazard to the individual, at least three sets of variables have to be taken into account:

- (a) The nature of the pulse: Intensity, duration, reverberance and whether it is discrete or repetitive.
- (b) The length of time of exposure of the man to the hazard.
- (c) Individual variation in susceptibility to hearing damage.

These variables have been taken into account by various authorities in deciding damage risk criteria for impulse noise. The technicalities involved in devising these criteria and their detailed application are not relevant to this paper. In essence they are criteria for estimating the length of time of exposure to noise of varying intensity and type that men can be reasonably safely subjected to bearing in mind differences in susceptibility to hearing damage.

In a practical application of such criteria, Elwood, Brasher and Croton (1970) have calculated critical daily exposures for men wearing ear plugs (see below) to weapon-produced impulsive noise. From examination of these results it is apparent that the authors have pinpointed the situations of maximum hazard making it quite clear which men are at risk with each weapon. The great value of such information in the prevention of hearing damage is self-evident.

Substitution or modification of noise sources

Actual substitution or modification of the noise source is usually not possible as the main demanding criteria of weapon design such as ballistic performance, weight, reliability and cost override any other consideration. Nonetheless, in peacetime, modification of the circumstances of their use may significantly reduce noise hazard.

This preventive method, or rather lack of it, is exemplified in the design of small-arms ranges. Too often the firing points or butts have walls in front or behind them providing hard, reflective surfaces likely to convert a simple pulse into a longer lasting, more dangerous reverberant pulse. Spacing of marksmen at the firing points could be increased as sound pressure from a source in the open is governed, by and large, by the inverse square law and a small increase in the distance from the source will result in an appreciable drop in SPL at the recipients ear. In normal practice however, time and numbers of men to fire conspire to defeat this principle and marksmen are rarely separated by more than two metres.

Recruit selection and audiometric follow-up

Ideally, with unlimited numbers of recruits and virtually unlimited diagnostic facilities noise induced hearing damage could be prevented by exposing recruits to a set amount of rifle fire and taking only those who show no resultant TTS. Plainly, this is not feasible but it is possible to do two things:

(a) Exclude by examination, both clinical and audiometric, men with pre-existing ear disease or hearing deficit.

(b) Establish a base line of hearing acuity audiometrically for each man on enlistment. Thereafter regular audiometric checks of their hearing could be done throughout their service careers so enabling doctors to detect any deterioration and take appropriate action by excluding the soldier from the hazard.

Cable and Morris (1971) have suggested that audiometry for recruits be done at three-monthly intervals, for infantrymen at six-monthly intervals and for those soldiers not regularly exposed to gunfire, annually.

Ear protection

Undoubtedly, the first protection against excessive noise was the dirty tips of index fingers firmly stuffed into the auditory meati but by the 19th century cotton wool was

used and continued to be used until the Second World War. In 1946, Stewart and Barrow demonstrated that it gave virtually no protection at all. In late 1943 the United States Navy developed a neoprene ear plug that appeared to be particularly effective and this was the forerunner of the V51R ear plug which is now standard issue to all ranks in the Army.

The V51R is merely a soft plastic ear plug which, when fitted accurately to the individual, completely occludes the meati and effectively attenuates sound. It does have disadvantages. One severe defect is that it attenuates not only harmful noise but also the whole range of speech frequencies. This very often makes orders difficult to hear when the plugs are being worn and obviously may be the cause of accident due to an order being missed or misheard. The plugs are uncomfortable to wear and are easily lost. They may predispose to the development of otitis externa, particularly in the tropics.

Glass down may also be used as an ear plug and has the advantage of comfort and disposability. Its main disadvantage is, that to be fully effective it must be correctly formed and inserted into the meati.

Fluid sealed ear muffs (FSED) give the best attenuation and are comfortable to wear. They are however expensive, bulky and share the defect of the V51R and glass down in that they attenuate speech frequencies. Headsets worn by armoured vehicle crews and some gunners in self-propelled guns are primarily designed to provide communication. They do nevertheless provide protection against noise approximately on the scale of the FSED.

A promising recent development is the Gundefender (Forrest and Coles 1970). This is, like the V51R, a plastic insert to fit into the external meatus but differs in that instead of being solid it encloses a metal plate perforated by a hole of critical diameter to afford progressive impedance to increasing amplitude of noise. Thus there is an increasing attenuation as the SPL exceeds 110 dB. This device therefore allows speech to be heard normally but gives about the same level of protection against impulse noise as the V51R. It also shares the V51R's disadvantages of relative discomfort and ease of loss.

Health education

Three main points must be put over to the soldier if the aim of prevention of noise induced hearing damage is to be achieved.

First, the soldier must be left in no doubt at all that excessive noise will permanently damage the hearing of a large proportion of people exposed to it. Second, he should be made aware of the sources of such dangerous noise. Finally, he must be encouraged to make full use of ear protection at all times when firing is going on.

If these three principles can be successfully impressed upon him much of the work of prevention is done.

Discussion

The nature of impulse noise, its damaging effect upon hearing, some indication of the prevalence of noise induced hearing loss among soldiers and general preventive measures have already been described. The implications of, and difficulties imposed by these factors need now to be examined both from the point of view of the soldier and from that of the Service in general.

As has been seen, the risk to hearing from impulse noise was emphasized by the large number of soldiers affected in the last world war. In the post-war years it seemed that this lesson learned in war, like many others, was being forgotten in the peace. But, with the introduction of a new family of more powerful weapons in the late 1950's and early 60's (notably the SLR), the problem of hearing damage became more apparent. Considerable concern arose over this aspect of the health of the soldier which was probably not unconnected with the changing attitude of the Service as an employer. With the ending of conscription in 1962 the regular soldier had become a highly skilled specialist and was correspondingly expensive to train and maintain. Plainly, any factor leading to deterioration or wastage of such a costly item assumed much greater importance than it could ever have had in the days of cheap and plentiful National Servicemen. Accordingly there was much research undertaken by the Army Personnel Research Establishment and other agencies of the other two Services to define the nature and extent of the noise problem. This led to specific advice being tendered to the Ministry of Defence which resulted in a Defence Council Instruction in 1966 authorising the general issue of V51R ear defenders (Croton 1971) and which directly resulted in a fairly widespread awareness and appreciation of the hazard of impulse noise and its prevention.

Thus, by 1966 there had been an implicit acceptance of some responsibility for this particular aspect of the soldier's health. However the Service was now in the unenviable position as an employer of being aware of the occupational risk of the soldier but being hampered in the prosecution of effective preventive measures by virtually irreconcilable difficulties.

The first of these difficulties must be that due to operational requirement. Theoretically, the Army exists in peacetime to train for war and in wartime to effect by force of arms the will of the people as expressed by Parliament. Unfortunately, nowadays, the condition of peace and war are seldom clear-cut and the British Army has been continuously involved operationally in different places since 1945. Herein lies the difficulty. Because operational requirements make such demands upon the soldier and life-threatening risk is so relatively common, the problem of hearing damage is understandably somewhat neglected. If this is so in "peacetime", how much more so in war!

During operations a soldier's exposure to noise can either be predicted or altered. Time and facilities do not allow elaborate periodic audiometric screening. Ear protection may or may not be worn—in many situations it would be positively dangerous to do so. Orders must be plainly heard. Sentries, say, in jungle warfare, must be able to hear the faintest sounds accurately. Here there is a paradox: wearing the present generation of ear defenders will reduce the ability to hear orders and faint noises, however a soldier who has suffered TTS through lack of ear protection will not hear them either. A further example is the case of a signaller with a high frequency impairment of hearing. He may have to turn the gain on his set up to such a high level in the attempt to hear speech that the noise in his headset exceeds the level at which his hearing is again at risk.

The solution, an obvious compromise, is to wear ear protection at all times when and where it is safe to do so, but a certain degree of unavoidable risk will have to be accepted for some individuals on operations.

A second problem is that having decided when and where the soldier is to wear ear protection, of making him do it. Contrary to much modern opinion outside the Service

the soldier is both highly individualistic and is well endowed with resourcefulness and guile. Without a rigid, grossly authoritarian regime, a type of discipline now generally discarded, some men will evade wearing ear defenders because they find them uncomfortable, because their Company Commander or Company Sergeant Major does not wear them, because they think them "cissy" or merely because they are too idle to put them in.

The only answer is health education and much is done, both on a corporate basis and individually by unit medical officers and regimental officers, but, in this, as in many other things, it has had limited success.

It has been mentioned above that the establishment of hearing standards and periodic audiometric screening of soldiers could isolate the susceptibles who would then be protected by removal from the hazard. This has considerable practical difficulties. Consider the equipment and trained manpower needed to screen regularly, at least annually, a constantly shifting population of about 170,000 men scattered (even now) world-wide.

What of the position of the susceptibles discovered? What is to be done with them? How can an infantryman or gunner be properly employed without firing rifles or guns? If they are given effective protection and allowed to carry on, what happens on operations where the wearing of ear protection may not be feasible? What happens and who will be responsible if they fail to use ear protection supplied? Consider the case of the soldier discovered already deafened by noise during his service and in consequence fallen below the minimum fitness standard for his trade and arm. Is he to be permanently medically downgraded thus often forfeiting any chance of promotion? Is he to be discharged, perhaps with a disability pension, cutting short an intended and possibly promising career?

Obviously, from the point of view of the Service there are moral, legal and compensatory responsibilities. How are these responsibilities to be assumed and to what extent? It should be noted in this respect that in civil life these three factors, so often bound together, are gaining increasing recognition and limited prescription has already been introduced for some forms of impulse noise induced deafness (Secretary of State for Employment's report to Parliament, 1973).

This recognition of the problem of impulse noise must be, and is, paralleled by a similar process in the Army. However, because of the unanswered (and at present unanswerable) questions posed above, this is far from easy and progress for the foreseeable future will be tentative and slow, balancing upon the one hand the natural concern for the health of the soldier and, on the other hand, the unavoidable need of the Service to put that man at risk.

The problem for the future is still further complicated by the hazard of excess steady-state noise in the soldier's environment. This has not been considered in this paper but must not be forgotten in any hearing conservation programme as it is even more pervasive (and just as damaging) as impulse noise.

Conclusion

Effective action to safeguard hearing is made difficult enough by the factors described above. It is made even more so by the general lack of basic information, partly

on the clinical entity of impulse noise deafness (in particular clarification of the relationship TTS bears to PTS) but, much more importantly at this stage, on the epidemiological aspects of the disease.

Nevertheless, in the last few years progress has been made in the early identification of those at risk, their assessment and subsequent protection. But, at the risk of being tedious, it must be re-stated that there is still a lack of valid epidemiological evidence upon which a really effective hearing conservation programme must depend. In this, the Army is in a similar position to the whole of British Industry; it has, however, incomparably larger medical resources per capita and a more intense preventive effort is both necessary and possible.

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